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Оцінка та прогнозування техногенного впливу на довкілля

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ESTIMATION OF KEY PRESSURES ON PRUT RIVER BASIN IN UKRAINE

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Purpose. To identify the main pressures, both anthropogenic and natural origin, on Prut River basin in Ukraine (within Ivano-Frankivsk and Chernivtsi regions) and to estimate the risks for water bodies in the pilot area. **Methodology.** The assessment is based on Methodology of Pressures/Impact Analysis and Risk Assessment prepared by expert group of the project "Environmental protection of International River Basins" in accordance with requirements of the EU Water Framework Directive. **Results.** We have described the point and diffuse sources of pollution of the river basin. As a next step, we have presented the characteristic of natural factors adverse effect on the river basin and have analyzed the total load of waste water and pollutants that negatively affect water quality. Moreover, we calculated the pressure indicators from agriculture and livestock based on available statistic data. **Originality.** For the first time, we have applied approaches of EU Water Framework Directive for risk analysis in Ukrainian part of Prut River basin. **Practical value.** These studies are the basis for determining the environmental objectives for each river basin areas (water body), development of future monitoring programs, planning and implementation of basic and additional measures to support or to achieve a high status or good ecological potential of rivers. **References 3, figures 4. Key words:** Prut River basin, anthropogenic pressure, point and diffuse sources of pollutions, natural factors, pressure indicators.

ОЦІНКА КЛЮЧОВИХ НАВАНТАЖЕНЬ НА БАСЕЙН РІКИ ПРУТ В УКРАЇНІ

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Проаналізовано основні навантаження, як антропогенного, так і природного походження, на басейн ріки Прут в межах України (Івано-Франківська та Чернівецька області). Описано точкові та дифузні джерела забруднення річкового басейну; дано характеристику природним факторам негативного впливу на річковий басейн; проаналізовано сумарне навантаження стічних вод та забруднюючих речовин, що погіршують якість води; обраховано індикатори навантаження на річковий басейн від сільського господарства та тваринництва. Ці дослідження є основою для визначення екологічних цілей для кожної ділянки річкового басейну (водного тіла), розробки моніторингових програм та планування і впровадження базових та додаткових заходів задля підтримки високого статусу чи досягнення доброго екологічного потенціалу річок. Це відповідає методологічним підходам Водної Рамкової Директиви ЄС щодо управління водними ресурсами і забезпечує виконання зобов'язань в рамках Плану дій з реалізації Угоди про асоціацію між Україною та Європейським Союзом на період 2014-2017 роки.

Ключові слова: річковий басейн Пруту, антропогенне навантаження, точкові та дифузні джерела забруднення, природні фактори, індикатори навантаження.

PROBLEM STATEMENT. Prut River is one of the largest rivers in Western Ukraine, Moldova and Romania, and one of the main tributaries of the Danube. In Ukraine Prut runs on Ivano-Frankivsk and Chernivtsi region. Prut River basin is under the pressure of nature and anthropogenic factors. The increase of anthropogenic impact on water resources causes increase of adverse natural phenomena and processes [1].

The main anthropogenic pressures on the quality and quantity of water resources in the Prut River basin are point and diffuse sources of pollution, related to discharges of insufficiently treated urban wastewater, rain-storm runoffs, and inadequate management of municipal, livestock and industrial wastes, agriculture etc. As a result river water quality has being deteriorated. Detailed analysis of pressure indicators has been done for Prut basin in its Ukrainian part by expert group in accordance with EU Water Framework Directive within the EU project "Environmental Protection of International River Basin" (EPIRB Project) implemented by Consortium led by Hulla & Co. Human Dynamics KG.

EXPERIMENTAL PART AND RESULTS OBTAINED. Wastewater treatment plants (WWTP) of most settlements in the Prut River basin are point sources of pollution of surface water bodies in the Prut basin. In the current economic situation, all these

structures are inefficient (Figure 1). They are sources of multi spectrum pollutants, including organic matter, nutrients (particularly, nitrogen and phosphorus) and different chemical pollutants.

Besides, most of industrial enterprises and tourist complexes discharge their treated or low treated wastewaters to the rivers.

For the assessment of pressure of Untreated Waste Waters (WW) related to emissions of Biochemical Oxygen Demand (BOD₅), Chemical Oxygen Demand (COD), Nitrogen (N_{tot}) and Phosphorus (P_{tot}) into the environment the inventory of the Wastewater treatment in agglomerations with population near 5 000 to more than 10 000 of Prut River Basin (UDRB) was done according to the Guidance Documentation Pressure/Impact Analysis (Risk Assessment) addressing hydromorphology and physic-chemistry in the EPIRB Project Pilot Basin. Total emissions and total load of pollutants from different agglomerations are presented in the Figure 2 and Figure 3.



Figure 1 – Wastewater discharges into surface water bodies of the Prut river basin, Ukraine (mln. m3), 2013



Figure 2 – Emissions of BOD₅, COD, N_{tot} and P_{tot} from non-treated waste waters in the Prut River basin, Ukraine

The levels of canalization of communal wastewaters in rural areas in the Ivano-Frankivsk and Chernivtsi Regions are low. According to National Report on Drinking Water Quality and Water Supply in 2011 the level of sewer coverage of the settlements in Ivano-Frankivsk region had one of the lowest figures in Ukraine and it was in total 4%, in details: for cities – 100%, for townships – 45.8% and for rural areas - only 0.8%. In the same time the proportion of people, who used the sewer in this region was in total 32.1%, in

cities -73.2%, in townships -43.2% and in rural areas -0.4%.



Figure 3 – Total emissions of Biochemical Oxygen Demand (BOD₅), Chemical Oxygen Demand (COD), Nitrogen (N_{tot}) and Phosphorus (P_{tot}) into the Prut River basin, Ukraine

The situation with access to sewer in the Chernivtsi region is low too. In 2011 sewer coverage of the settlements was in total for Chernivtsi region 6.2%, including for cities – 81.8% for townships – 87,5% and for rural settlements – 2.5%. A part of population, who used canalization, was in this region in total 27.2%, including in cities – 71.1%, in townships – 19.6% and in rural areas only - 0.7%.

Significant number of agglomerations (small towns, townships and rural settlements) is located in pilot area and has decentralized sanitation systems (septic tanks and pit latrines), which generate diffuse organic, nutrients and microbial pollutions of local water resources. No detailed data exists about this large component of the wastewater production.

Two pressure indicators were calculated in accordance to EPIRB Project Guidance Document: Untreated wastewaters load in relation to the annual minimum flow of river and Total share of wastewater in the river.

Based on the results, Prut River within Yaremche town is possibly at risk from point source – WWTP taking into account the loads from tourists. Prut River in Kolomyya and Chernivtsi is at risk.

Indicator of Untreated waste waters load was calculated according to the following equations:

For collected and untreated waste water Dww = L / Qmin,r(1)And for collected and treated wastewater $Dww = (L^*(1-\eta)) / Qmin,r(2)$

Description of used variables:

D_{ww}: Specific wastewater discharge into the respective river water body;

L : Total (dimensionless) load equivalent originating from wastewater discharge into the river in terms of number of inhabitants connected to the sewerage system;

 $Q_{\min,r}$; Annual minimum flow m³/s;

 η : Treatment efficiency, reflected the level of the performance of the treatment plant (for secondary treatment it is 0,9 for BOD, 0,75 – for COD and 0,9 – for NH₄ (according to Guidance Document).

Other pressure indicator due to point sources pollution: Total share of wastewater in the river.

Indicator of Total share of waste water in the river was calculated according to the follow in equation:

Sww =
$$\sum Qww/MQr$$
 (3)

Description of used variables:

Sww: Total share of waste water in a river at a given cross section along the river;

Qww: Total of all (current/future) wastewater discharges into the river $[m^3/s]$;

MQr: Mean annual flow of the river $[m^3/s]$.

Risk assessment for this indicator has been done for 53 enterprises (point sources of river water pollution). As a result of the assessment all River Water Bodies receiving waste water from 53 point sources were defined as not at risk.

Analysis of long term monitoring data on phenols, oil products and surfactants content in River WBs provided by Central Geophysical Observatory for the period 2000-2011 shows that rivers are under significant loads of phenols (2-41 times multiplicity of maximum allowable concentration exceeding) and oil products (1,2-18,2 times). The content of total phenols in the rivers can be of natural and anthropogenic original and needs further investigation and monitoring with clarification of the method of detection and verification in other laboratories.

Usually the low or not treated industrial wastewater discharged into communal sewage networks or directly to the water bodies, the unauthorized disposal of waste, often unsatisfactory state of landfills for disposal of waste, lack of drainage systems at many industrial sites, closed water systems, dust- and gas-cleaning equipment generate the impacts on surface and ground waters.

Anthropogenic pressures on surface and groundwater resources also come from diffuse sources: non-compliance with water conservation and protection zones; unregulated discharge of municipal wastes, particularly in rural localities; storage of pesticides and chemicals; diffuse pollution from transportation (pollutant emissions, run-off from roads) and agriculture (use of pesticides, run-off from farms); etc.

The main diffuse sources of pollution in Prut River basin:

- rain-storm runoffs in Chernivtsi, Kolomyya and other settlements situated nearby the water bodies of the pilot basin as the storm water disposal and treatment systems are not existed in these areas and the untreated storm runoffs are flowing to the nearest water bodies and so polluting them;

- effluents from industrial sites and legal and illegal landfills so they pollute the neighboring water bodies with fuels and lubricants, oil products and heavy metals, plastics, hazardous substances of infiltrates from the landfills;

- runoffs from farmlands which carry dissolved mineral fertilizers, chemicals and pesticides;

- effluents from animal farms and poultry farms;

- effluents from settlements, cottage townships, individual tourist complexes, hotels and restaurants that are not connected to sewer and equipped properly with waste water treatment systems; – effluents from deforestation, forest logging roads and tractor logging trails, lead to faster destruction of soil and forest ecosystems and have an negative impact on the water bodies by increasing of solid runoff and decreasing of water quality and natural flood protection capacities of the adjacent territories.

The agricultural pollution factors (using fertilizers, livestock breeding, excessive grazing of pastures) are referred to as diffuse (non point) sources of pollution. It is well known that the applying fertilizers for crop production affect the quality of the ground and surface waters.

The results of pollution monitoring did not prove any significant impact of the above mentioned factors on the river as a whole, being considered mostly as local sources of pollution. The volume of introduced fertilizers can be estimated considering the statistics for separate districts.

A total volume of mineral fertilizers applied over Chernivtsi region in 2011 was 107.3 thousand centners with an average of 88 kg per hectare of crops. Only a small volume of fertilizers is introduced in the mountain area (30-40 kg/ha), while a considerably greater volume is used in the planes. In general, the level of fertilization of the Prut river catchment may be considered equal to the average indicator over the region. The same situation is for the organic fertilizers, although only limited data is available in this respect – 0.5 tones/ha.

The handling of hazardous and domestic wastes is among the major environmental problems in the Prut River basin in Ukraine.

In Chernivtsi region there are 11 municipal solid waste landfills with total area of 67 ha. Of these 8 (with total area of 32 ha) do not comply with their designed capacity. In some areas, rural landfills are an issue [2].

According to data from the State Statistical Committee of Ukraine, in 2011 Chernivtsi region generated over 225 000 t of waste, 160 000 of which came from the city of Chernivtsi. The drastic increasing of solid wastes production and the lack of equipped landfills facilitate results in the infiltration of extremely hazardous toxic, carcinogenic chemicals and biological pollutants into ground and surface waters. Within this study no information was found on the qualitative composition of infiltrates from the major landfills in the basin area.

From 24 investigated rivers in Prut basin 6 were identified as river at risk, 3 - possibly at risk and 15 - not at risk. The analysis of the long term data for the critical water quality parameter on NH₄ shows that there is a substantial impact on water quality, which can be a result of the lack of the waste water treatment, taking into account that this pollution associated with discharges of low or untreated domestic wastewater.

High and medium floods caused by heavy rains occur in the Prut basin, which form in the basin water catchment area in Ukraine's Carpathians. Basin floods are multiple and depend on cyclonic activity over the catchment area. During warm periods and depending on river flow, from 2 to 8 heavy rains per season may cause floods.

Water erosion from heavy pruning and lateral

erosion of slopes, on slopes - natural denudation and erosion, complicated in some treeless areas, landslides, avalanches, screes and quicksand are the modern exogenous geodynamic processes in river valleys of Prut basin. As a result of these processes in rivers and streams comes much diverse-grained material, which then transferred waterways. The fate of suspended sediment can be dominant. The largest part of the solid runoff of mountain rivers associated with mud flow. Almost all of the tributaries of the Prut River are under mud flows influence, especially rivers: Kamyanka, Zhonka, Meresnyi, Zhenets. On the Figure 4 runoff hydrograph of Prut River according to data of Carpathian mudflow station is presented.



Figure 4 – Runoff hydrograph, Prut river basin (Yaremche hydrological post, 2008-2011)

Flood protection measures include improvements in monitoring practice, damming, straightening of river courses, and strengthening of river banks. In the mountain parts of the basin, one of the popular bank strengthening measures is building of gabion walls. For the flood protection the accumulative-flood storage constructions in the mountains and on the plains, as well as polders and flood reservoir and landslide and mud protection constructions are built in the basin. All above mentioned factors cause morphological alterations of Prut River basin.

There are three derivative mini hydropower plants (HHP) in the Prut River basin: Probiynivska, Holoshynska and Snyatynska. To maximize power generation, each year large volumes of water are diverted from riverbeds to HPPs. It creates serious environmental problems, such as habitats are destroyed, fish fail to reproduce; aquatic organisms disappear, including insects and fish entered in the Red Book of Ukraine.

According to information from Dniester-Prut Basin Management Administration, 202,3 km of sections have been regulated in Ivano-Frankovsk Region and 123,4 km in Chernovtsy Region (2012).

Extraction of riverine alluvium is one of the major environmental problems in the basin. In many cases, gravel extraction occurs spontaneously in all rivers of the Prut basin without any approvals, often in places where there is a chance to drive. The consequence of a gravel extraction is a reducing of the riverine alluvium marks for Prut and Cheremosh river beds to 1-1.5 m down, and near Chernivtsi it reduced even on 2-2.5 m. The significant flood protection complex was built in

the basin of the Prut. However, it is based only on the regulation of riverbeds and river flow (bank protection constructions, protective levees) and does not provide regulation of surface overland flow in watersheds of the rivers and doesn't increase water accumulation capacity of the area.

Deforestation, forest logging roads and tractor logging trails, great recreational load on some tourist routes, overgrazing of cattle, etc., in many cases lead to faster destruction of soil and forest ecosystems and have a negative impact on the water bodies by increasing of solid runoff and decreasing of water quality and natural flood protection capacities of the adjacent territories [2].

Timber harvesting and logging at forest cutting is performed manually or by using mechanisms. For logging forest on cutting areas and to transport timbers to the main roads the forestry tractors are used and the temporary tractor roads are laid on the mountain slopes. After finishing work on cutting areas these temporary tractor roads are affected actively by water erosion, which in many cases leads to the linear erosion. Sometimes gravity and natural water logging under significant slopes and specific lithological content of the native rocks lead to formation of the landslides. Most widespread and threaten consequence is a linear (depth) soil erosion on logging tractor roads. Maximum soil washed from fresh cutting areas is up to 600 tons per hectare per year.

As a result of such activity rivers and streams are fed by big amount of different size gravel materials which are transferred by waterways. The content of suspended solid runoff can be substantial. Due to the existing big areas of sedimentary rocks, which are easy eroded, the Upper Prut basin is characterized by high sediment runoff, especially suspended.

Tourism and recreation is a critical anthropogenic factor in upstream of Prut river basin. Available natural recreation resources in the region are 1,4-1,8 times higher than in average in Ukraine. Rivers, first of all the Prut and the Cheremosh rivers, play an important role in tourism development in the region, including water tourism. The famous tourist center is Yaremche. Near 50 hotels and mo than 5000 Green Tourism manors are in operation. In the Polyanytsya there is a new the biggest mountain-skiing resort "Bukovel". This type of economic activity causes extra sources of point and diffuse pollution of water resources.

Illegal stone, sand and gravel abstraction from rivers causes deformation of river bed, change runoff, increases risk of flooding. Fish industry in the Prut basin does not have substantial development. It is because water on the river Prut is generally cool and rich of suspended sediment. Favourable conditions for fisheries occur in the flat part of Chernivtsi region.

CONCLUSIONS. The main anthropogenic pressures on the quality and quantity of water resources in the Prut River basin are point sources of pollution, related to discharges of insufficiently treated urban wastewater, discharges of industrial wastewater, and inadequate management of municipal, livestock and industrial wastes.

Anthropogenic pressures on surface and groundwater resources also come from diffuse sources: non-compliance with water conservation and protection

zones; unregulated discharge of municipal wastes, particularly in rural localities; storage of pesticides and chemicals; diffuse pollution from transportation (pollutant emissions, run-off from roads) and agriculture (use of pesticides, run-off from farms); etc. Certain natural factors influence the quality and quantity of water resources in the basin: intensive rainfalls and flooding. These contribute to higher flushing of wastes, solids, and chemicals (from agriculture) off water catchment areas and into waters, and so pollute water resources.

Based on the result of risk assessment, environmental objectives and protected measures could be elaborated for each area of Prut River basin as well as a monitoring programme could be designed.

The main basic measures to maintain the status of water bodies with high (excellent) or good status and to restore status for the poor status water bodies are determined by legal framework existed in Ukraine, which include the Ukrainian laws, state and regional programs/plans of measures, bylaws and broad spectrum of regulatory and technical norms, which regulating the activities in the field of water protection and usage [3]. The broad legal framework on water issues includes numerous special water and waterrelated legislation. For approximation of EU Water Framework Directive into the Ukrainian legislation the recommended actions, needed to implement in the legal framework of Ukraine, responsible authorities and deadlines are dedicated already.

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ОЦЕНКА КЛЮЧЕВЫХ ДАВЛЕНИЙ НА РЕЧНОЙ БАССЕЙН РЕКИ ПРУТ В УКРАИНЕ

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Проанализированы основные нагрузки, как антропогенного, так и природного происхождения, на бассейн реки Прут в пределах Украины (Ивано-Франковская и Черновицкая области). Описаны точечные и диффузные источники загрязнения речного бассейна; дана характеристика природным факторам негативного воздействия на речной бассейн; проанализированы суммарная нагрузка сточных вод и загрязняющих веществ, ухудшающих качество воды; рассчитаны индикаторы нагрузки на речной бассейн от сельского хозяйства и животноводства. Эти исследования являются основой для определения экологических целей для каждого участка речного бассейна (водного тела), разработки мониторинговых программ, планирования и внедрения базовых и дополнительных мер для поддержания высокого статуса или достижения хорошего экологического потенциала рек. Это соответствует методологическим подходам Водной Рамочной Директивы ЕС по управлению водными ресурсами и обеспечивает выполнение обязательств в рамках Плана действий по реализации Соглашения об ассоциации между Украиной и Европейским Союзом на период 2014-2017 годов.

Ключевые слова: речной бассейн Прута, антропогенная нагрузка, точечные и диффузные источники загрязнения, природные факторы, индикаторы нагрузки.